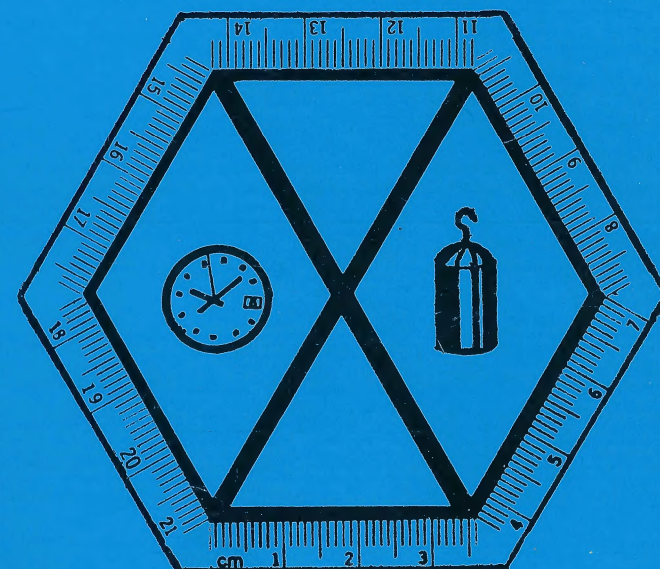
CROSS EDUCATIONAL SOFTWARE
1802 N. Trenton St.
P. O. Box 1536
Ruston, Louisiana 71270

PHYSICS

VOLUME 6

THERMODYNAMICS



CROSS EDUCATIONAL SOFTWARE
Computer Physics Series

T H E R M O D Y N A M I C S

Steve Kamm
South Oklahoma City
Junior College
7777 South May
Oklahoma City, OK 73159

Mark Cross
Grambling State Univ.
Grambling, LA 71245

Paul Stephenson
LA Tech University
Ruston, LA 71270

INTRODUCTION

Volume six in the college physics series has these programs:

THERMODYNAMIC PROCESSES	CALORIMETRY
THERMODYNAMIC CYCLES	IDEAL GAS CYCLES
HEAT ENGINES - THEORY	MOLECULAR MOTION AND PRESSURE
HEAT ENGINES - APPLICATIONS	DEMUFFIN

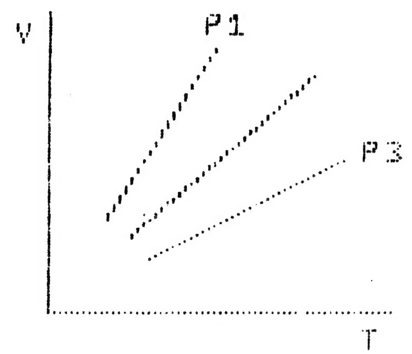
plus several other text and binary files used by "Ideal Gas Cycles".

IDEAL GAS CYCLES was written by Paul Stephenson. MOLECULAR MOTION AND PRESSURE was written by Mark Cross. Steve Kamm wrote all of the others.

This diskette uses Apple DOS 3.3. If you have an older disk drive with DOS 3.2 then you will have to BRUN DEMUFFIN to convert the whole disk. Take a blank diskette initiallized under DOS 3.2, plus this physics programs diskette, to a friend who has DOS 3.3. He will show you how to convert the programs to DOS 3.2.

SECOND PRINTING MARCH 1983

Isobaric process on a V-T diagram

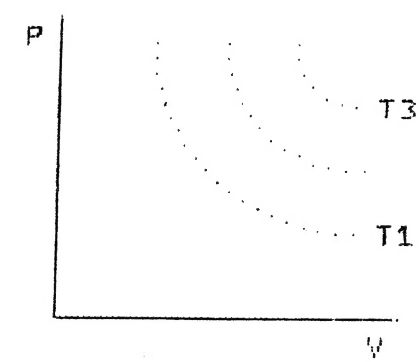


THERMODYNAMIC PROCESSES

The program draws isobaric, adiabatic, isometric, and isothermal processes and asks questions about them. It begins with a true-false quiz about the definitions of these processes. Next it draws families of curves for an ideal gas with different numbers of molecules going through each process. The curves are repeated on P-V, P-T, and V-T graphs. Examples are shown below. Finally it asks the viewer three questions like this one:

(UNDER A GRAPH OF A SLANTED LINE ON A V-T DIAGRAM)
IS THIS: 1. ISOTHERMAL ON V-T DIAGRAM
2. ISOBARIC ON V-T DIAGRAM
3. ISOBARIC ON P-T DIAGRAM
ANSWER 1, 2, OR 3:

Isothermal process on a P-V graph

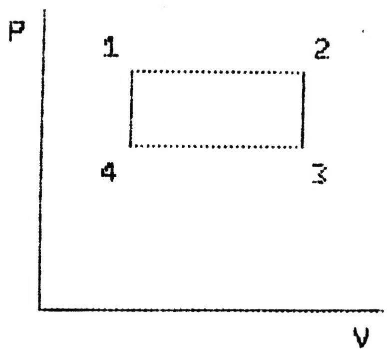


THERMODYNAMIC CYCLES

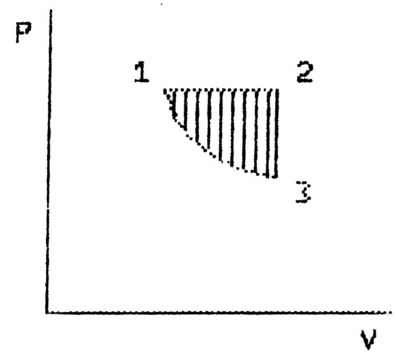
This program assumes the viewer has seen "Thermodynamic Processes". It builds on that program to combine the basic processes into cycles.

The first cycle illustrated has isobaric expansion, then isometric cooling, then isobaric compression, and finally isometric heating. It is a rectangle on a P-V diagram. The program shades in the area below the isobaric expansion and then it subtracts the area under the compression to get the net work.

FIRST CYCLE



SECOND CYCLE



The program studies a second cycle made by an isobaric expansion combined with an isometric cooling followed by isothermal compression. It draws the cycle as before. Then it discuss finding the net work by integrating PdV with the ideal gas equation.

The program briefly mentions the Carnot cycle. It says that the cycle is made of 2 isothermal processes and 2 adiabatic processes, and that it results in the maximum possible efficiency.

HEAT ENGINES – THEORY

This program is meant to be used for further study after the Carnot cycle has been presented in a physics lecture. It begins with a reminder that the Carnot cycle gives the best possible efficiency of a heat engine or pump, but real engines have less than this efficiency.

The program shows an animated heat flow diagram for an engine with the hot reservoir on the top, the cold on the bottom, and work being extracted at the side. Then it says that a heat pump is the opposite, and draws a pump with heat moving from the cold to the hot area.

Using the standard notation with "1" being the hot temperature, heat engines have efficiency = W/Q1. Heat pumps have coefficient of performance K = Q2/W. These formulas are also presented in sentence form. Next come three T/F questions:

1. Use efficiency for heat pumps? T or F?

2. Q2 is measured in degrees Kelvin? T or F?

3. K = W / Q2 T or F?

The viewer is expected to get all three answers right.

These final two formulas are presented with some text: W = Q1 - Q2; and Q1/Q2 = T1/T2. Then the program uses them to solve this problem:

A heat pump operates between -10 degrees and 25 degrees celsius. How much work must be done to extract 200 calories of thermal energy from the low temperature sink?

HEAT ENGINES – APPLICATIONS

This program applies the theory of heat engines to particular problems involving ideal engines and refrigerators. The viewer should have a pencil, paper, and calculator. It starts with this review and summary:

T1 = HIGH TEMP SOURCE (KELVIN)
T2 = LOW TEMP SINK (KELVIN)
Q1 = HEAT FLOW FROM HIGH TEMP
Q2 = HEAT FLOW FROM LOW TEMP
W = WORK DONE BY THE ENGINE
EFF= EFFICIENCY = W / Q1
K = HEAT PUMP PERFORMANCE = Q2 / W

RELATIONSHIPS: W = Q1 - Q2 ; Q1 / Q2 = T1 / T2

PROBLEMS SOLVED:

(1) How much useful work can be extracted from an ideal heat engine operating between 200 degrees and 105 degrees celsius if 1 kcal of energy is supplied?

(2) An ideal refrigerator extracts heat from a storage chamber at -15 degrees and exhausts it at 40 degrees celsius. How many kcal are extracted if 100 joules of work are supplied?

(3) What is the maximum possible efficiency of a steam engine if the temperature of the input steam is 175 degrees and the exhaust is 75 celsius?

(4) An engine absorbs 500 kcal of heat at 600 degrees kelvin and exhausts heat at 300 kelvin. What is the efficiency and how much heat is exhausted, assuming an ideal engine?

(5) A Carnot engine operates between 20 and 500 degrees celsius. How much energy must be supplied to produce 10,000 joules of work?

CALORIMETRY

When you start with a hot sample and put it into a cup of cool liquid, both come to the same temperature. The program shows this process with pictures.

The law of conservation of energy says that the heat lost by the hot object equals the heat gained by the cold cup and the liquid. Heat energy for these problems is calculated from specific heat times mass times temperature change. After presenting this theory, the program asks the viewer to make a blank chart like the one below. Some teachers might want to leave blank copies of this chart beside the computer.

	C	M	T (start)	T (end)
1				
2				
3				

Next the program solves the six problems listed below. After the third problem, the computer teaches the concept of the water equivalent of an object. It uses this idea in the fourth problem. It teaches about the heat of fusion between problems 4 and 5.

Problem 1. A 600 gm copper cup (c = .093) holds 1500 gm of water at 20 degrees C. A 100 gm sample of iron (c = .11) at 120 degrees C is put in the water. What is the final temperature?

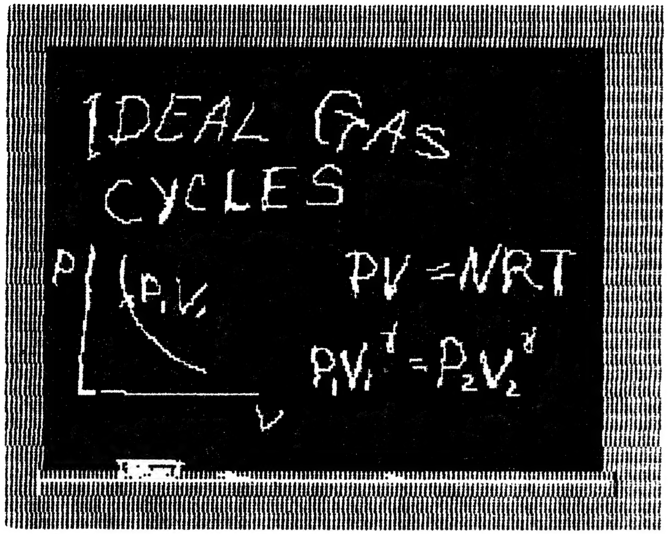
Problem 2. A 300 gm glass container (c = .14) holds 500 gm of water at 30 degrees C. When 500 gm of alcohol at 75 degrees are added, the mixture reaches a final temperature of 46 degrees C. What is the specific heat of the alcohol?

Problem 3. A 450 gm piece of lead is heated to 100 degrees C and then dropped into a 500 gm copper (c = .093) calorimeter cup which contains 100 gm of water at 10 degrees C. After mixing, the temperature of the water has increased 11.1 degrees. Find the specific heat of the lead. Hint: the equilibrium temperature is not 11.1 degrees!

Problem 4. A calorimeter (water equivalent = .03 kg) holds 500 gm of water at 15 degrees C. A 560 gm sample of copper (c = .093) is added. If the final temperature of the water is 22.5 degrees C, find the initial temperature of the copper.

Problem 5. A 30 gm piece of ice at zero degrees C is placed in 210 gm of water at 30 degrees C. Neglecting heat losses to the environment, what is the final temperature?

Problem 6. 500 gm of lead (c = .03) pellets at 100 degrees C are poured in a hole in a large piece of ice. How much ice is melted before the lead cools to zero?



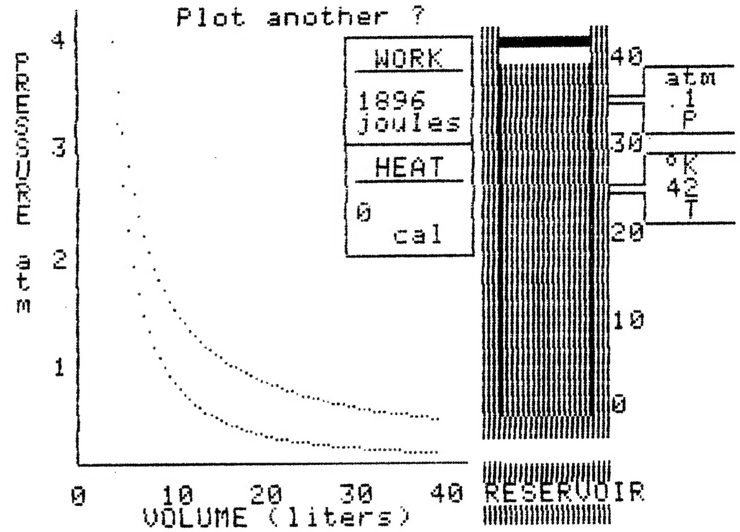
IDEAL GAS CYCLES

This program simulates an ideal gas enclosed in a cylinder with a moveable piston. Several processes may be performed on a monatomic, diatomic, or polyatomic ideal gas. Although the use of a textbook by the student is assumed, he can summon some definitions and general instructions by pressing the "ESC" key when the computer is waiting for a numerical response, but not from the main menu.

The menu gives seven choices:

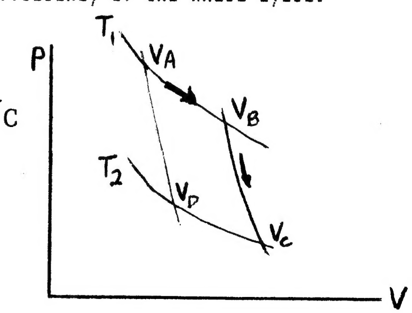
1. ISOTHERMAL EXPANSION
2. ADIABATIC EXPANSION
3. ISOBARIC EXPANSION
4. ISOCHORIC PROCESS
5. RECTANGULAR CYCLE
6. CARNOT CYCLE
7. REFRIGERATOR CYCLE
8. QUIT

Choices 1-4 allow the user to pick the beginning and end points of the process. Pressure is in atmospheres and volume in liters, making the Ideal Gas equation: P V = .0823 T. The program plots the chosen process on a graph like the one below. The gas expands and contracts in the cylinder at the right side of the picture and the heat reservoir is connected or disconnected as required. The user can plot several processes on one graph to build up a whole cycle.



Choices 5-7 allow the user to specify the four quantities that determine a closed cycle. For the Carnot and refrigerator cycles, the user picks the upper temperature and three of the volumes. Then the computer goes through the cycle, moving the gas up and down in the cylinder and calculating the heat and work as it goes. At the end it prints the efficiency of the whole cycle.

The user picks
T_1, V_A, V_B, V_C



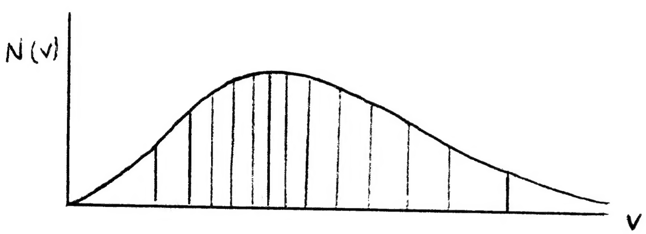
MOLECULAR MOTION AND GAS PRESSURE

This program simulates the motion of ideal gas molecules. They bounce around at random in a cylinder, sometimes hitting the pressure gauge on the right side. Every hit on the gauge causes a temporary small pressure. The pressure fluctuations are smoothed out a little and then graphed in the middle of the screen.

This demonstration prepares students for the derivation of the relation between gas kinetic theory and the average pressure. They can watch wall collisions and their effect in making pressure fluctuations.

The program is easier to use if people know about the repeat key. It can be held down together with another key such as "M" for more molecules.

The gas particles have a Maxwellian distribution of speeds. The whole theoretical distribution is divided into twenty bins of equal probability. That is, the area in each bin is the same on the graph of n(v) versus v. New molecules are assigned to a random bin to get their speed. They are then placed in the center of the cylinder and started moving in the general direction of the lower right corner.



The temperature originally is proportional to the average speed squared. To save time, later temperatures are found from changes in the speeds. If the speed of every molecule increases by a factor of 1.2 then the temperature goes up by the square of this, or 1.44 times. At the same time the whole Maxwellian distribution in the graph above would be multiplied by 1.2.

PROGRAMMING DETAILS

THERMODYNAMIC PROCESSES and THERMODYNAMIC CYCLES use text and the high resolution screen HGR. They have no unusual programming tricks. Their main program flows from line 100 through to about 800 with very few branches out to subroutines, except for frequent jumps to line 10050 to wait for the user's carriage return.

ENGINES: THEORY uses text and animation on the low resolution screen. ENGINES: APPLICATIONS is straight text problem solving with no graphics animation.

CALORIMETRY uses some low resolution graphics plus a lot of text. Its structure is the same as the above four programs; a main program that flows straight through from line 100 to about 800.

IDEAL GAS CYCLES is extremely complex. It uses both high resolution screens. The Basic code resides above the second screen HGR2 when it runs. Machine language routines and other small items are stored in the normal program space between memory locations 2048 and 8192. All this configuration is set up by the disk file EXEC AUTO. This file loads some binary files, sets up the start of program pointer, and then RUNs the main program: GAS.COM.4. Once IDEAL GAS CYCLES is running, it gives beautiful high resolution graphics using the character generator in Apple's DOS TOOL KIT.

There is an error handling routine at program line 13000 in case someone presses control-C or gives a simple carriage return when asked for a number. This simply prints an error message and returns to the main menu. The proper exit from the program is choice 8 on the menu, "QUIT". That choice goes to line 20000 of the program, which does a "RESET" and an "FP" to escape the high resolution character generator and get the Apple back into a standard configuration. The user should type in RUN MENU at this point to get a new program.

IDEAL GAS CYCLES grew too big for memory. The first thing that was discarded was several REM's. Fortunately, the internal program notation is similar to a physics text so a person familiar with thermodynamics can follow it. The second thing discarded was a lot of the text messages, such as instructions. These are out on disk storage until the program needs them. This program uses all of the mysterious binary and text files on the thermodynamics disk.

MOLECULAR MOTION AND GAS PRESSURE is another program that uses tricks that could potentially create trouble. The program does most of its display on the HGR2 screen. It draws text on this screen with shape tables. If there is a control-C or a request to "Q" (quit) then the program jumps to line 280 which resets TEXT and stops the program.

The program has two machine language portions appended to its end. The first is a shape table used to draw text on the high resolution screen.

The second is a machine language subroutine called "MOVE" in line 100. This does several things very quickly. (1) It moves all N% molecules ahead one time step, calculating the new positions and plotting them. (2) It increments the instantaneous pressure P% by adding to it the speed of every particle that hits the right wall of the cylinder. (3) It increments the time TI% and shifts the graph left if the time is greater then 248. This subroutine INSISTS that the variables in line 1000 be defined first before any other variables in memory. The "MOVE" routine needs to find these variables in a certain place.

Positions (X%, Y%) and speeds (V%, W%) have been scaled to maintain precision. They are plotted 16 times smaller than the way they are stored in memory. That is, X = X + V for moving particles precisely but HPLOT X/16, Y/16 is done to display the particles.

MEMORY USAGE:

2048 - 10000 (roughly)	= main Basic program
16384- 24576	= HGR2 screen for the display
24576- 26199	= machine language routine to move all the molecules
26200- 31000 (about)	= variable storage

SUGGESTED CHANGES

The pressure is smoothed out in this line:

```
110 P5 = (9 * P5 + P%) / 10
```

P% is the pressure from molecules that hit the pressure gauge recently. P5 is a longer time averaged pressure. If line 110 is deleted then the pressure graph will have more spikes on it. On the other hand, the amount of time averaging can be increased for a smoother graph. For example, P5 = (P5 * 20 + P%) / 21 will make a very smooth pressure graph because it gives little weight to the new pressure fluctuation P%. (The molecule moving subroutine "MOVE" internally smoothes out the pressure P% by taking the hits from molecules plus 15 times the old P% and dividing by 16.)

The command keys are in lines 205-225 and 800-830. They can be other letters.

The factor T2 in lines 620 and 650 controls how much the temperature changes every time a key is pressed. It can be bigger for faster changes.

The maximum number of particles is 127. The MOVE routine can't handle any more.

The mimimum temperature is 2 degrees in line 650. If T is below 2 then the program won't let the gas get colder. This is because it has trouble restarting the molecules after they have stopped at absolute zero. The maximum temperature is 2500 degrees in line 600. There is no good reason for this particular number, except that at higher temperatures the molecules sometimes bounce from top to bottom of the cylinder in a single time step and confuse the MOVE routine.

Lines 10-20 draw the text string M$ on the high resolution screen at cursor position CH, CV

Lines 100-190 are the main moving and plotting loop. The program spends most of its time in here letting the gas move and waiting for a user command.

Lines 200-225 pick the place to go after a user presses one of the allowed commands.

Lines 300-340 add one more molecule at the center of the gas cylinder.

Lines 344-348 clean up the screen after an error message.

Lines 350-395 remove one particle, the last one numbered N%.

Lines 400-440 calculate and print the temperature. They are only used once when the program is initiallizing.

Lines 600-640 make the gas hotter. They multiply the speed of every particle by the factor T2. They multiply the 20 segments of the Maxwellian distribution by T2. They also multiply the temperature by T2 squared.

Lines 650-670 make the gas colder by the factor T2.

Lines 700-720 set up the number bins in the Maxwellian distribution.

Lines 750-770 set the speed and direction of a new particle (J)

Lines 800-840 draw the command list on the screen.

Lines 1000-3200 print the title, draw the display, and initiallize all of the constants.

Line 63999 sets up a pointer to the ASCII shape table that is appended to the end of line 63999.

```
63999 Z9 =  PEEK (121) + 256 *  PEEK (122):Z9 = Z9 + 73:
      POKE 232, Z9 - INT (Z9/256) * 256:
      POKE 233, Z9 / 256 : RETURN :REM SET UP SHAPE TABLE
```

--- HIDDEN SHAPE TABLE FOLLOWS AFTER THIS LINE ---
MOSTLY ASCII LETTERS FOR HI-RESOLUTION TEXTS

--- A MACHINE LANGUAGE PARTICLE MOVING ROUTINE ---
FOLLOWS AFTER THE SHAPE TABLE

A scene from Molecular Motion and Gas Pressure: